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How Multimodal Examinations Can Increase Sustainable Student Gain by Aligning Teaching and Assessment

Abstract: Modern industry and multi-discipline projects require highly trained individuals with resilient science and engineering back-grounds. Graduates must be able to agilely apply excellent theoretical knowledge in their subject matter as well as essential practical "hands-on" knowledge of diverse working processes to solve complex problems. To meet these demands, university education follows the concept of Constructive Alignment and thus increasingly adopts the teaching of necessary practical skills to the actual industry requirements and assessment routines. However, a systematic approach to coherently align these three central teaching demands is strangely absent from current university curricula.

We demonstrate the feasibility of implementing practical assessments in a regular theory-based examination, thus defining the term "*blended assessment*". We assessed a course for natural science and engineering students pursuing a career in biomedical engineering, and evaluated the benefit of blended assessment exams for students and lecturers. Our controlled study assessed the physiological background of electrocardiograms (ECGs), the practical measurement of ECG curves, and their interpretation of basic pathologic alterations. To study on long time effects, students have been assessed on the topic twice with a time lag of 6 months. Our findings suggest a significant improvement in student gain with respect to practical skills and theoretical knowledge. The results of the reassessments support these outcomes. From the lecturers´ point of view, blended assessment complements practical training courses while keeping organizational effort manageable. We consider blended assessment a viable tool for providing an improved student gain, industry-ready education format that should be evaluated and established further to prepare university graduates optimally for their future careers.

Keywords: constructive alignment, examination, long-term retention, multimodal, practical learning

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1 Introduction

Studying is booming! Within the last decade the total number of students at German universities increased by more than one third to approx. 2.89 million (2019/20) [1]. At the same time, the demands placed by industry and employers on future employees changed dramatically along with it: According to a study conducted on behalf of the German Chamber of Commerce and Industry in 2015, German industrial employers are looking primarily for such skills as "being teamplayers", "being able to work independently" and "high communication skills" in general when assessing graduate students [2]. Moreover, employees with strong academic backgrounds naturally qualify as future team leaders and managers. Such qualifications include practical soft skills such as communication and moderation skills, team-minded actions, and presentation skills [3]. Industrial employers call for graduates, who combine the theoretical as well as the practical knowledge in both specialized "hard-fact" contexts as well as "soft-skill" settings to handle the challenges placed upon them on the volatile modern job market [4].

Despite revolutionary processes, such as the Bologna reform, aim to improve overall teaching worldwide, there is still a remarkable misconception that teaching and the responsibility of the lecturer ends with the lecture itself and the actual process of studying is in the sole responsibility of the students. Instead, the concept of constructive alignment (CA) requires that the teaching process inevitably includes appropriate teaching scenarios and respectively tailored assessments: in CA teachings are constructed to lead towards congruent assessment in a goal-oriented manner [5]. Here it is assumed that "assessment drives learning" in order to establish fundamental and long-term learning processes. Further

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benefits arise from synchronizing teaching and assessment with self-regulated learning (SRL), allowing students to study at their own capacities, e.g. by offering more open forms of studying, which trains key qualifications that are useful and important for the handling of academic tasks [6].

In the present study, we report on the implementation of a blended standard and practical assessment in a standard written examination, henceforth called blended assessment. It is implemented in an established course of students from natural science and engineering backgrounds. By comparing to a control group that was examined by a standard assessment and a voluntary re-testing six months after the original exam, we are also able to quantify the student gain from practical testing and describe trends in its long(er)-term effects. Our study provides a model approach on how to use constructive alignment in a science exam to implement the examination of practical skills to improve teaching and outcome for students in order to be fit for future job requirements in general.

2 Methods

2.1 Course and Practical Skills Tested

We have implemented our study in the existing course "Introduction to medicine for natural scientists and engineers" during regular operation. In this elective course, among others, the practical use of electrocardiogram (ECG) hand-held devices is taught and studied practically.

The course comprises 360 Bachelor and Master students yearly. The students are enrolled for physics, computer sciences and information technology, electrical and mechanical engineering, mathematics, biology and computational engineering sciences (in decreasing order). Over the course of two semesters, students visit a weekly lecture of 2 hrs and a practical course of 1 hr. The practical course consists of a problem-based learning (PBL) course in the first semester and a problem-based practical learning (PBPL) course in the second semester (s. Figure 1). Written examinations are offered twice a year.

As ECG is taught in the practical course intensively, we can test our working hypothesis is that practically taught and assessed skills are available to the examined students for a longer period of time (i.e. are more sustainable) and are furthermore potentially even learned better, i.e. give a better score in the examination.

2.2 Realization of blended assessment

Due to legal constraints, the blended assessment was set up as a bonus assignment in direct succession to the regular exam (90 min written examination). We reserved an extra 30 min after the regular exam ended for the bonus assignment:

- 5 min for explaining the task and distributing the portable ECG-devices (Vernier; USA) and bonus assignment,
- 5 min for the students to read the assignment,
- 15 min to work on the assessment and
- 5 min for recollecting the ECG-devices.

The students were preassigned to the blended or the standard assessment according to their curricular requirements. From this preselected group, students were chosen randomly for blended assessment. 25 students were randomly chosen for blended assessment (3 students did not show up, rendering the group of blended assessment participants 22 out of 91 totally assessed students). The remaining 69 participants were presented an assignment covering the same learning aims as the ECG-group, but had to solve it in a standard pen-and-paper assessment (further on referred to as standard assessment). Blended assessment participants were seated in a separate lecture hall during the entire exam in order to not disturb others when ECG-devices were distributed.

The students' participation in this study was voluntary. All students had been informed about the bonus assignment 3 months prior to the exam via electronic notice and furthermore by announcement during the lecture. 2.5 months prior, one 1.5 h-hands-on course was offered on a voluntary basis offering free time to familiarize with the ECG-devices once more after the practical course had been completed successfully and to ask specific questions to the teaching staff. The chronology of the course and the blended assessment examination study is summarized in Figure 1.

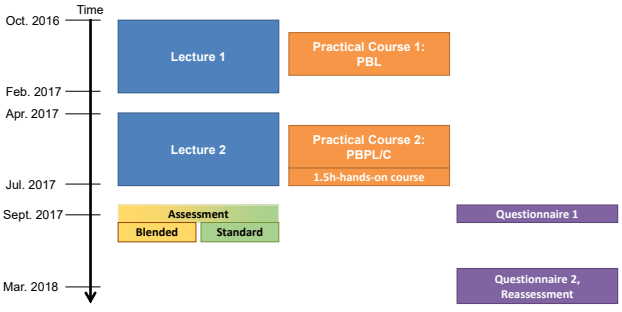

Figure 1: Time line of the course work, consisting of the lecture and paralleled practical courses 1 and 2 teaching methods of problem-based learning (PBL) and problem-based practical learning / course (PBPL/C).

All data were randomized and anonymized before data analysis by a staff member different from the examiner analysing the data to avoid bias effects. Student consent was obtained after the bonus exam allowing us to use the data for research purposes and only the data of those students was used for analysis, who agreed on it.

2.3 Data Processing and Statistics

We averaged the points earned per individual assignment (arithmetic mean) for the group of blended assessment, standard assessment and for both groups together. Error bars represent the mean standard error. Statistical significance between the average points earned by the blended assessment group and those of standard assessment was analysed using two-tailed T-testing with a significance level of $\alpha = 0.05$ and assuming significance for $p<0.05$, high significance for $p<0.01$ and very high significance for $p<0.001$.

3 Results

3.1 Assignment Score

Comparing the group solving the blended assignment practically (N = 22) to the group solving the standard assignment (N = 69), we observe a significantly ($p<0.05$) improved performance of the practically assessed group. For the total points earned, we find a high significance (Figure 2a): With blended assessment scoring (7.55 ± 0.40) compared to (6.08 ± 0.28) for standard assessment ($p<0.01$).

A total of N = 31 students (5 from the originally practically assessed group) have been assessed on the assignment after six months. Students were asked to take the same test again, only theoretically and unprepared now, to test longterm residual knowledge. We observe a slightly improved performance for the group formerly tested practically in the exam, however, this trend is not significant (Figure 2b).

3.2 Assignment Adequacy

In order to evaluate the (subjective) adequacy of the assignment, we asked students to rate the difficulty level of the assignments in self-evaluation after the exam. Students rate the difficulty of the assessment between 4 and 5 points out of 10 (most difficult), with a slightly lower difficulty for the blended assessment student group (Figure 3). For an objective estimation of the difficulty level, we calculated the mean total points reached by all participants in the assessment to (6.43 ± 0.24), (maximum 10 points; s. Figure 2b) i.e. on average, 64% points were scored. Both results, from self-evaluation as well as from the averaged points, allow the conclusion that the assignment was adequately posed for the student body.

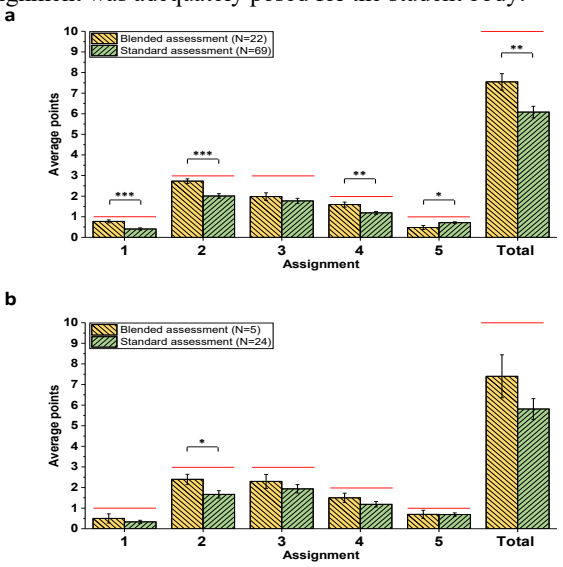

Figure 2: Mean points per assignment achieved by the different groups for (a) the assignment during the exam and (b) the theoretical assignment tested in self-assessment after six months. Maximum points possible to earn are marked with a red bar. Significant (t-tested) differences are marked (*: $p<0.05$, **: $p<0.01$, *** $p<0.001$).

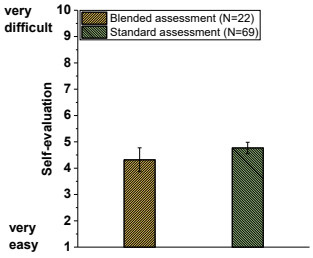

Figure 3: Self-evaluation on assignment adequacy. Question: How do you evaluate the level of difficulty of the assignment?".

4 Discussion and Conclusion

Increasing student gain during the learning process as well as for their general education as future employees is a challenging task that requires 1) a multimodal teaching and examination methodology, that is 2) embedded in constructively aligned curricula, and 3) must be sufficiently accepted by student. Only then, relevant hard and soft skills are developed sustainably [7]. In the following, we discuss these three requirements based on the a.m. results of our study.

Generally, our results suggest that practically assessed students score higher in the (bonus) assignment than their theoretically working colleagues. However, this statement must be interpreted in the context that the usage of the ECG device was taught practically in the practical course. Therefore, we hypothesize that the application of knowledge during assessment is easier for the practically assessed student group. Our results support the tendency that the performance of the practically assessed students was generally better during assessment (Figure 2a). We attribute this to the more efficient and adequate training for the practical assignment during the practical course as part of the mandatory course work. This fact is strongly supported by the improved long-term scores of the practically working group after six months (Figure 2b). Here we see that the main steps necessary for successful application of the ECG device are better memorized by the formerly practically assessed students – even though the examination was standard ("pen-and-paper") based (Figure 2b). We conclude from this that the practically tested students seem to absorb and memorize the knowledge better. A possible explanation for this could be sought in the multimodal learning approach [8] the following way: Practical preparation during PBPL/C addressed all students visually, haptically, tactilely thereby challenging their cognitive learning channels on multiple levels. Recalling such multimodally acquired knowledge practically, i.e. by again addressing multi-channel incentives, makes the application of knowledge easier for the blended assessment group [8]. In other words, the standard assessment group required more translational capacity during examination, as only the cognitive and visual channels were addressed during assessment. This is supported by Magana et al., whose results showed an improved learning for students assessed multimodally (haptically and visually) versus students only allowed visual feedback during assessment [9].

In this work, we demonstrate the successful implementation of multimodal practical assignments using electrocardiogram (ECG) devices in an otherwise traditional pen-and-paper examination for students. We could show that such blended assessment significantly improved students' results on reproductive and interpretation tasks during assessment, which is in line with applying the concepts of constructive alignment.

We could also see a positive trend for a long-term memorization. However, the lecturer and teaching staff must also not be forgotten, as they must be willing to prepare well for such blended assessment: The necessary preparations of devices and the additional organizational effort consumes resources, but it is essential for the correct implementation of the practical exam.

One way of combining practical and theoretical aspects in one single exam is by teaching practical or theoretical subjects in blocks. As such, different subjects are taught in only one individual block, avoiding inter-subject entanglement during the teaching phase and isolating subject specific modalities. Therefore, we opt for a blended assessment modality, allowing to test each skill with the modality that is best suited. This opens new perspectives for improving graduate education on all levels of teaching and through all disciplines and most importantly, allows for an adequate education of future employees of industrial companies, who seek more practically and theoretically savvy personnel.

Author Statement

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